ABSTRACT

Ground-level ozone (O_3) is a secondary air pollutant of global concern due to its adverse effects on human health, vegetation, and key role in atmospheric chemistry. This study aimed to investigate the spatiotemporal variability of O_3 concentration in a semi-urban traffic corridor in Kharagpur, India, under the influence of precursor emissions, meteorology, and traffic. On-site measurements of traffic, precursors, and meteorological variables revealed that O_3 concentrations increased from ~50-60 μg m^{-3} from morning to ~150-170 μg m^{-3} in early afternoon during pre-monsoon season. O_3 concentrations were comparatively lower (~30-50 μg m^{-3} in morning to ~90-120 μg m^{-3} during midday) despite higher TVOC and traffic volume during post-monsoon season. Temperature positively (r_s = 0.77-0.93) and RH negatively (r_s = -0.83-0.85) influenced O_3 concentrations in both seasons. NO_x and TVOC displayed different seasonal trends and CO and CO_2 concentration levels were closely linked with traffic peaks. Maximum O_3 levels occurred when NO_x < ~80 μg m^{-3}, TVOC ~40-60 μg m^{-3}, CO < 1000 μg m^{-3}, and traffic volume ~1100-1500 veh h^{-1}. Influence of wind speed and vehicle speed was not significant in pre-monsoon and TVOC was not significant in post-monsoon. Heavy vehicles contributed highest emission despite less in numbers in traffic fleet. Generalized Additive Models (GAM) were developed that perfectly captured the influence of predictors on O_3 concentration variability. Findings are supported by other powerful models (MLR, RF, XGBoost, ANN) and validated with 10-fold cross-validation. Single-factor GAM revealed that temperature, relative humidity, and air pressure exerted dominant nonlinear controls on O_3 concentrations. O_3 concentrations were most strongly influenced when traffic volumes were ~15-30 veh min^{-1} and vehicle speed was ~13-16 m s^{-1}. NO_x and TVOC showed regime-dependent effects with significant effects of TVOC in pre-monsoon and NO_x in post-monsoon season. Multi-factor GAM further explored significant paired interactions between predictors that contributed to high O_3 concentration levels. It explained 99.3-99.4% of O_3 concentrations with low RMSE (0.15-0.16) and MAE (0.11-0.13). The findings emphasize the requirement of season-specific emission controls (VOCs in pre-monsoon, NO_x in post-monsoon), optimized traffic management, and meteorological considerations for reduction of O_3 concentration in urban traffic environment.

Keywords: Ground-level ozone, Meteorology, Traffic, Generalized Additive Model, Temporal variability, Concentration, Emission factor